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# Patient Monitoring Low – Cost Automated Ventilator

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## Abstract
*This paper presents the design and development of a low-cost ventilator designed to address the critical shortage of ventilators during emergencies, such as the COVID-19 pandemic. The proposed ventilator is an affordable and efficient solution that integrates the essential features to support patients with respiratory issues. An Arduino-based system automates the operation of a silicone ventilator bag through a stepper motor-driven push mechanism, ensuring controlled air delivery to the lungs. The ventilator automatically adjusts air volume and pressure based on the patient's age group, with additional manual controls for caregivers to fine-tune the volume if necessary. The device monitors key patient vitals, including blood oxygen levels, heart rate, and temperature. A mobile app serves as the primary user interface, providing real-time feedback through an LCD and enabling caregivers to track vitals and make necessary adjustments. By incorporating a compact design and low-cost components, this project delivers a reliable and adaptable solution to assist patients in critical conditions during healthcare crises.*
***Keywords:*** *Arduino, Silicone Ventilator Bag, Stepper Motor, Blood Oxygen Level, Heart Rate, Temperature, User Interface, LCD.*

## 1. Introduction
The COVID-19 pandemic highlighted the critical need to strengthen global healthcare infrastructure, particularly in respiratory support. In India, this urgency led to an accelerated effort to increase ventilator production and expand access to critical care technology. However, despite the large-scale manufacturing of indigenous ventilators, many units remained unused due to concerns over their usability, performance, and adaptability in real-world settings. In addition, tragic incidents, such as the deaths of 24 patients in Nashik due to oxygen supply disruption, underscored the need for reliable and automated ventilator systems that can be used effectively in emergencies. Most existing ventilators are bulky, expensive, and require skilled operation, making them difficult to deploy in resource-limited settings or emergencies. Many also lack intuitive controls and real-time feedback mechanisms, which increases the potential for human error. To address these challenges, this paper presents the design and development of a low- cost, portable, Arduino-based automated ventilator system intended for use in home care, ambulances, and field environments. This ventilator features an intelligent control mechanism that adjusts air volume and pressure based on the patient's age, ensuring that the ventilation provided is appropriate for infants, adults, and elderly individuals. The system uses a linear actuator-driven arm to control the compression of an Ambu bag, with the pressure and volume calibrated according to the patient's age to avoid under- or over- inflation. Additionally, a manual override allows caregivers to adjust the ventilation settings according to the patient's condition. To improve usability, the system includes a real-time interface that displays vital patient information such as blood oxygen saturation ($SpO_2$), heart rate, and body temperature, which are measured using sensors like the MAX30100 and DHT11. These readings can be monitored remotely via a mobile app, powered by

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an ESP8266 module, allowing caregivers to make adjustments and track the patient's condition from a distance. This project aims to bridge the gap between cost- effectiveness and functionality in mechanical ventilation, offering a scalable and adaptable solution that can be used in critical care settings, especially during health emergencies or in low-resource environments.

## 2. Literature Survey

Firstly, we surveyed existing technologies for low-cost ventilator systems. This survey helped us understand which technologies, such as Arduino-based automation, airflow and pressure control, and real-time sensor integration, are suitable for our system to enhance efficiency, adaptability, and safety in resource-limited settings [1]. Another study presented a ventilator system using Arduino integrated with a blood oxygen sensor to monitor $SpO_2$ levels in real-time, allowing dynamic control of ventilation based on patient needs. This approach reinforces the importance of incorporating vital sign monitoring into the ventilator system, ensuring both responsiveness and patient safety. The paper also emphasizes cost-effective design using widely available components, which supports the feasibility of our goal to create an affordable and scalable solution [2]. Additionally, a study on a low-cost, automated, and portable ventilator demonstrates the use of an Arduino microcontroller and a 3D-printed mechanical structure to automate Bag Valve Mask (BVM) operation. The system offers adjustable tidal volume, breathing rate, and inspiratory-to-expiratory (I:E) ratio, providing adaptability to various patient conditions. Its modular, open-source design enhances customization and scalability, making it ideal for deployment in under-resourced healthcare environments. This supports our approach of combining Arduino-based automation with mechanical actuation for a flexible and efficient ventilator system [3]. Similarly, another study describes the design and implementation of a portable emergency ventilator for COVID-19 patients using an Arduino-controlled stepper motor to automate BVM compression. The system integrates a pressure sensor, temperature sensor, and pulse oximeter to monitor patient vitals in real-time, enabling responsive adjustment of ventilation parameters. The focus on affordability, portability, and feedback-driven control further supports the viability of our system in homecare and emergency settings, particularly in low-resource environments [4]. Furthermore, a health monitoring system integrated with a ventilator using Arduino emphasizes real-time monitoring of vital signs, such as heart rate and body temperature, using sensors like the pulse sensor and LM35 temperature sensor. This data is displayed on an LCD screen, aiding the caregiver in making timely decisions. The system's reliance on mechanical actuation and electronic integration mirrors our objective of creating a low-cost, reliable, and easy-to- use ventilator solution, especially for emergency care [5].

## 3. Proposed Methodology

The proposed ventilator system integrates a set of sensors, actuators, microcontrollers, and a Wi-Fi module to automate and monitor respiratory support. Input units include the MAX30100 sensor (for $SpO_2$ and heart rate), DHT11 sensor (for temperature and humidity), and a 10k potentiometer that allows manual control over the air volume. An Arduino Uno acts as the central control unit, driving a servo motor that compresses a silicone ventilator bag. The ESP8266 Wi-Fi module enables real-time transmission of patient vitals to a mobile application interface. The system is designed to operate based on three age groups namely Child, Adult, and Old with each category having pre-defined respiratory parameters such as breathing rate and volume to ensure appropriate ventilation support. While the LCD provides localized feedback on system parameters such as selected age group. tidal volume and servo angle, all vital signs ($SpO_2$, heart rate, temperature, and humidity) are exclusively displayed in the mobile app for live monitoring. The combination of cost-effectiveness, real-time remote access, and adaptability makes this design suitable for emergency and resource-limited scenarios [6]. The overall system architecture is represented in the block diagram below in figure 1 & 2 [7-12].

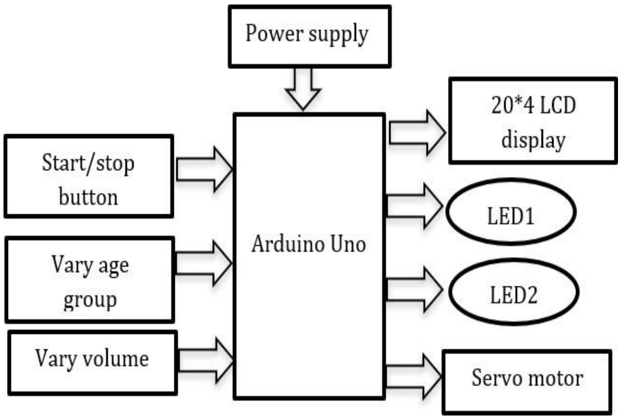


Figure 1 **Arduino Uno Control Section**

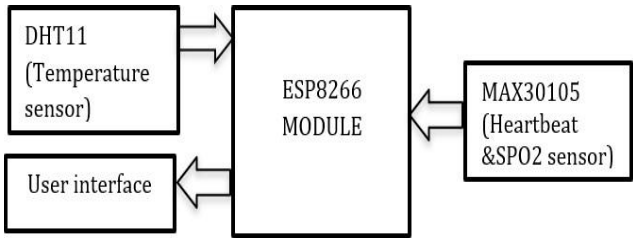


Figure 2 **ESP8266 Web Monitoring Section**

Key features of the proposed solution include:

- **Age Group Classification:** The system includes predefined breathing rates and tidal volume values for three age groups: Child, Adult, and Old. Based on the selected age group, the system automatically adjusts the servo motor compression to a specific volume.
- **Manual Volume Control:** A potentiometer is included in the design to allow caregivers to manually fine-tune the tidal volume if necessary. This adds flexibility in situations where automatic settings may not perfectly match individual patient needs.
- **Servo Angle Calculation:** The servo motor controls the compression of the ventilator bag based on the manually adjusted volume (from the potentiometer). The relationship between the set volume (v, in mL) and the corresponding servo angle is defined by the following cubic equation: Servo angle = 4.89e-7*v^3 - 8.4e-4*v^2 + 0.642*v + 28 This ensures precise control over bag compression, enabling accurate delivery of manually configured volume.
- **LCD Display Monitoring:** The LCD module displays ventilation-related data such as breathing mode, breath rate, servo angle, manual volume, potentiometer value, and breath count. This provides quick local access to essential operational information, especially during emergency use.
- **Realtime Web Monitoring:** Using the ESP8266 Wi-Fi module, the system transmits patient vital signs—$SpO_2$, heart rate, temperature, and humidity—to a mobile user interface in real-time. This feature enhances remote supervision and patient safety, especially in isolation zones or mobile care units, shown in Figure 3.

## 4. Flowchart

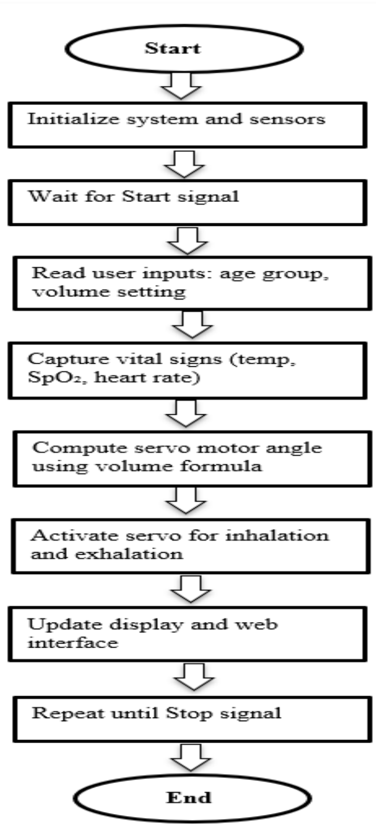


Figure 3 **Flowchart**

### 4.1. Algorithm

- Initialize () all modules
- If Start Button == HIGH:
- Read Age Group
- Set Breath Rate and Tidal Volume accordingly
- Monitor sensors: Temp, $SpO_2$, Heartrate
- Calculate servo angle.
- Control servo motor accordingly
- Send sensors data to Web interface.
- Loop until Stop Button == HIGH

### 4.2. Calculation

#### 4.2.1. Servo Angle Calculation

The servo motor's angle of rotation determines the compression of the ventilation bag, which directly controls the tidal volume delivered to the patient.

$$\text{Servo angle} = 4.89e\text{-}7*v^3 - 8.4e\text{-}4*v^2 + 0.642*v + 28$$

Where,
v = tidal volume in millilitres (mL) The resulting servo angle is in degrees
Higher tidal volume results in a larger servo angle
Lower tidal volume results in a smaller servo angle

#### 4.2.2. Breath Rate and Pump Delay Calculation

The breathing rate determines how frequently the servo compresses the bag. The pump delay (in milliseconds) between compressions is calculated using:

$$\textbf{Pump Delay} = \frac{6000}{\text{Breaths per Minute (bpm)}} \div 2$$

The division by 2 accounts for the inhale and exhale phases, assuming equal duration for both.
1 minute=60000 milliseconds.

## 5. Results and Discussion

After powering on the ventilator system, the module initializes successfully, and a "Ventilator Ready" message briefly appears on the LCD screen. Following initialization, the display updates to show default values—Mode: None, Status: OFF, and all parameters (Breath Rate, Volume, Angle) set to zero as shown in Figure 4. This confirms the system is in standby mode and awaiting user input, shown in Figure 4 to 6.


**Figure 4** Before Selecting the Age Group

Upon selecting a specific age group (Child, Adult, or Old) and pressing the start button, the LCD displays the corresponding predefined Breath Rate (BR) and updates the Mode accordingly. Simultaneously, the system allows manual control of Volume (V) and Angle (A) values using a potentiometer, and the breath cycle count begins. This dynamic functionality is observed in:


**Figure 5** The Child Mode is Enabled with a Breath Rate of 25


**Figure 6** The Adult Mode is Enabled with a Breath Rate of 16

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**Figure 7** **The Old Mode is Enabled with a Breath Rate of 12**

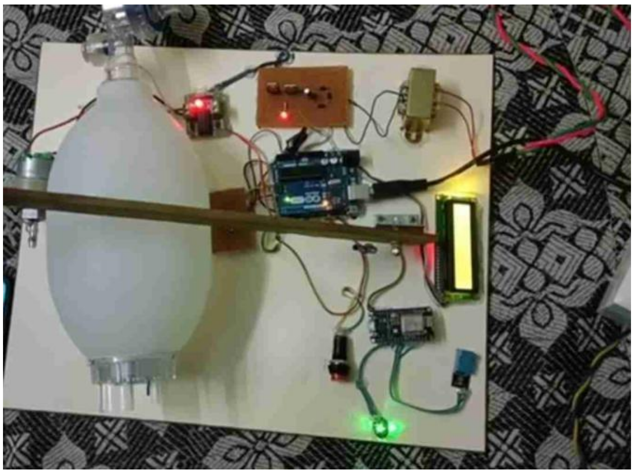

**Figure 8** **Prototype of the System**

Figure 7, These results validate the proper functioning of age- based ventilator settings and demonstrate real-time updates of parameters and system status on the display. The Status toggles between ON and OFF based on whether the ventilator is active or in standby mode. The overall prototype of the system is given in the figure 8. In addition to the ventilator control, the system incorporates real-time health monitoring using the MAX30100 (for heart rate and $SpO_2$) and DHT11 (for temperature and humidity) sensors. As shown in Figure 9, these sensors are connected to an ESP8266 Wi-Fi module, which collects biometric data when the user places their finger on the sensor. Upon establishing a Wi-Fi connection, the real-time values are transmitted wirelessly to a mobile application. The app interface, shown in Figure 8, displays key health metrics such as Temperature, Humidity, Heart Rate, and $SpO_2$, thereby enabling continuous and remote patient monitoring. This validates the successful integration of sensors and confirms the system's ability to collect and display health data reliably, shown in Figure 10 [13-15].

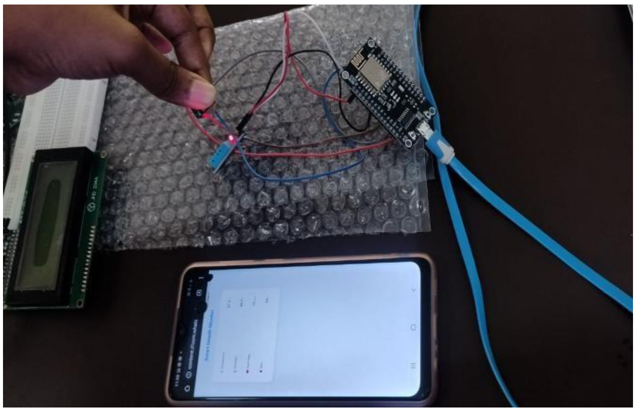

**Figure 9** **ESP8266 Web Monitoring System**

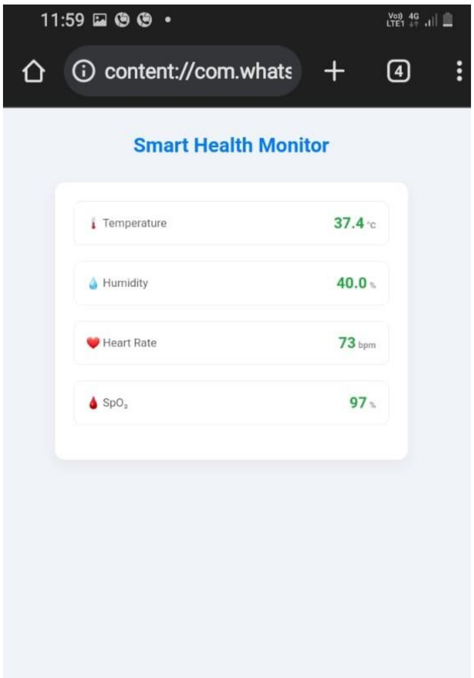


**Figure 10** **User Interface Displaying the Patient Vitals**

## Conclusion

The proposed low-cost automated ventilator offers a viable solution to medical resource limitations, particularly during pandemics and in resource-constrained environments. By automating ventilation based on age-specific parameters and integrating real-time monitoring features, the device ensures both efficacy and safety in patient care. Its affordability and portability make it ideal for deployment in ambulances, remote areas, and emergency healthcare situations. This system offers high versatility by supporting varied age groups and incorporating basic tuning options. The real-time data communication helps bridge the gap between the patient and the caregiver, allowing for timely interventions.

## Future Scope

Future enhancements for the ventilator system could significantly improve its functionality and user experience. Incorporating advanced machine learning algorithms could enable personalized respiratory therapy tailored to individual patient needs. To ensure reliability during power outages, integrating backup battery systems would provide uninterrupted operation. Cloud-based data logging could facilitate continuous patient record maintenance and remote access for healthcare providers. Enhancing mobile app functionalities would offer better user interaction, real-time alerts, and control. Additionally, features like voice control or remote configuration could empower caregivers to manage the system more conveniently and effectively, especially in home or emergency settings

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